Regionalization and GIS Use in the **Win**d **D**eployment **S**ystems Model (**WinDS**)

GIS and Regionalization Issues in EERE Modeling

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- WinDS Model Description
- WinDS-H2 Description
- GIS/regional inputs
- Reduced form effort

WinDS Model

(Wind Deployment Systems Model)

- A multi-regional, multi-time-period model of capacity expansion in the electric sector of the U.S.
- Designed to estimate market potential of wind energy in the U.S. for the next 20 – 50 years under different technology development and policy scenarios
- Two primary components – GIS and LP (linear programming)

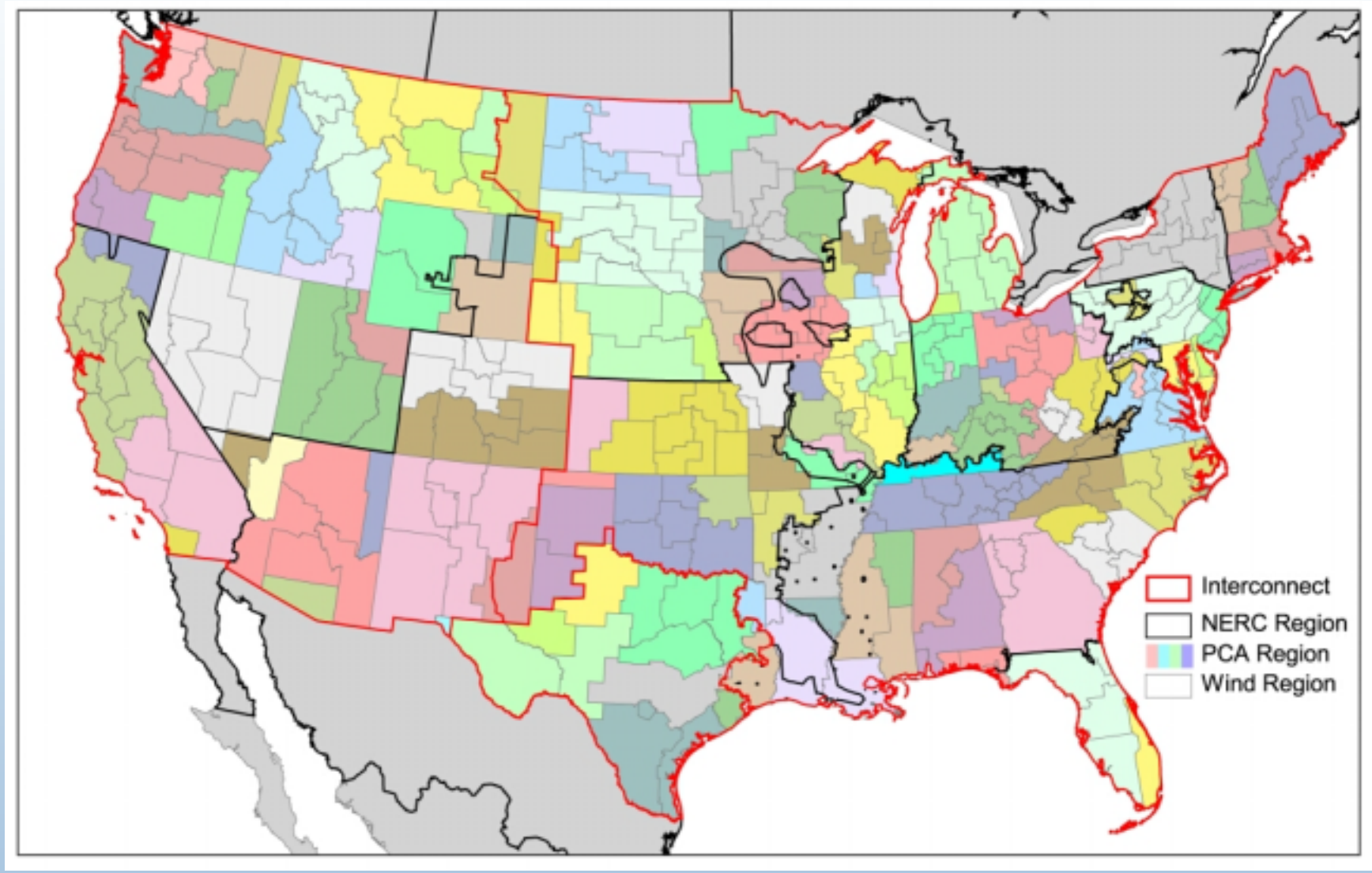
WinDS is Designed to Address the Principal Market Issues for Wind

- Access to and cost of transmission
  - Low quality wind close to the load or high quality far away?
  - How much wind can be transmitted on existing lines?
  - Will wind penetrate the market if it must cover the cost of new transmission lines?
- Intermittency
  - How does wind capacity credit change with penetration?
  - How do ancillary service requirements increase with wind market penetration?
  - How much would dispersal of wind sites help?
  - Is on-site storage cost effective?

WinDS Addresses These Issues Through:

- Many wind supply and demand regions
- Constraints on existing transmission available to wind
- Explicit accounting for operating reserves, wind oversupply, and for wind capacity value as a function of the amount and dispersion of wind installations
- Tracking wind installations by supply/demand region, wind class and transmission line vintage
- CAES or H2 storage increases capacity value, and reduces transmission costs and ancillary service requirements

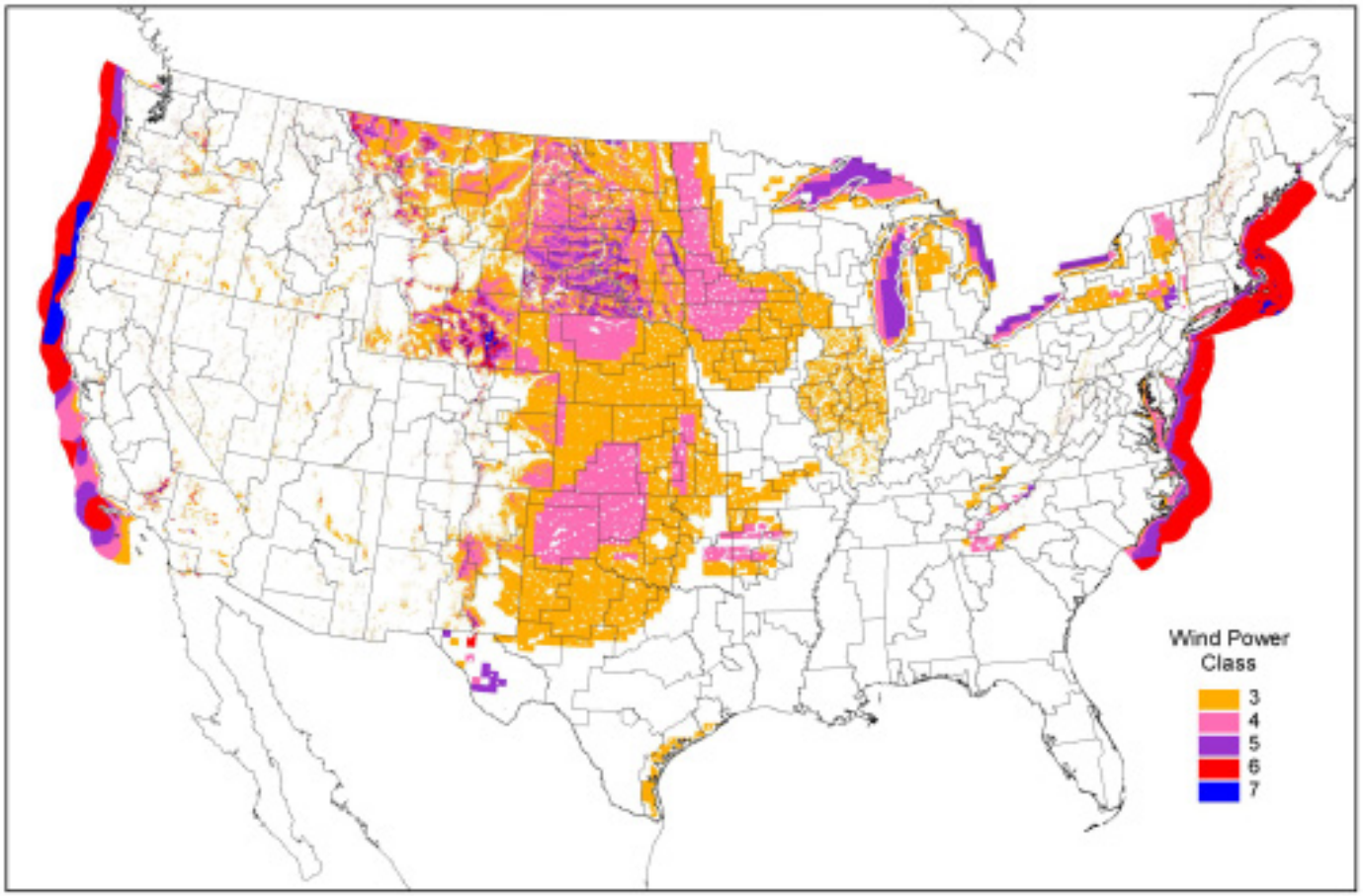
WinDS Regions



Characteristics of WinDS regions

- Four levels
  - Interconnects
  - NERC regions (matched to NEMS)
  - Power Control Areas (PCAs)
  - Wind supply/demand regions
    - Built up from counties
    - Never cross state lines
    - Assigned to a PCA
    - Separate wind resources from loads

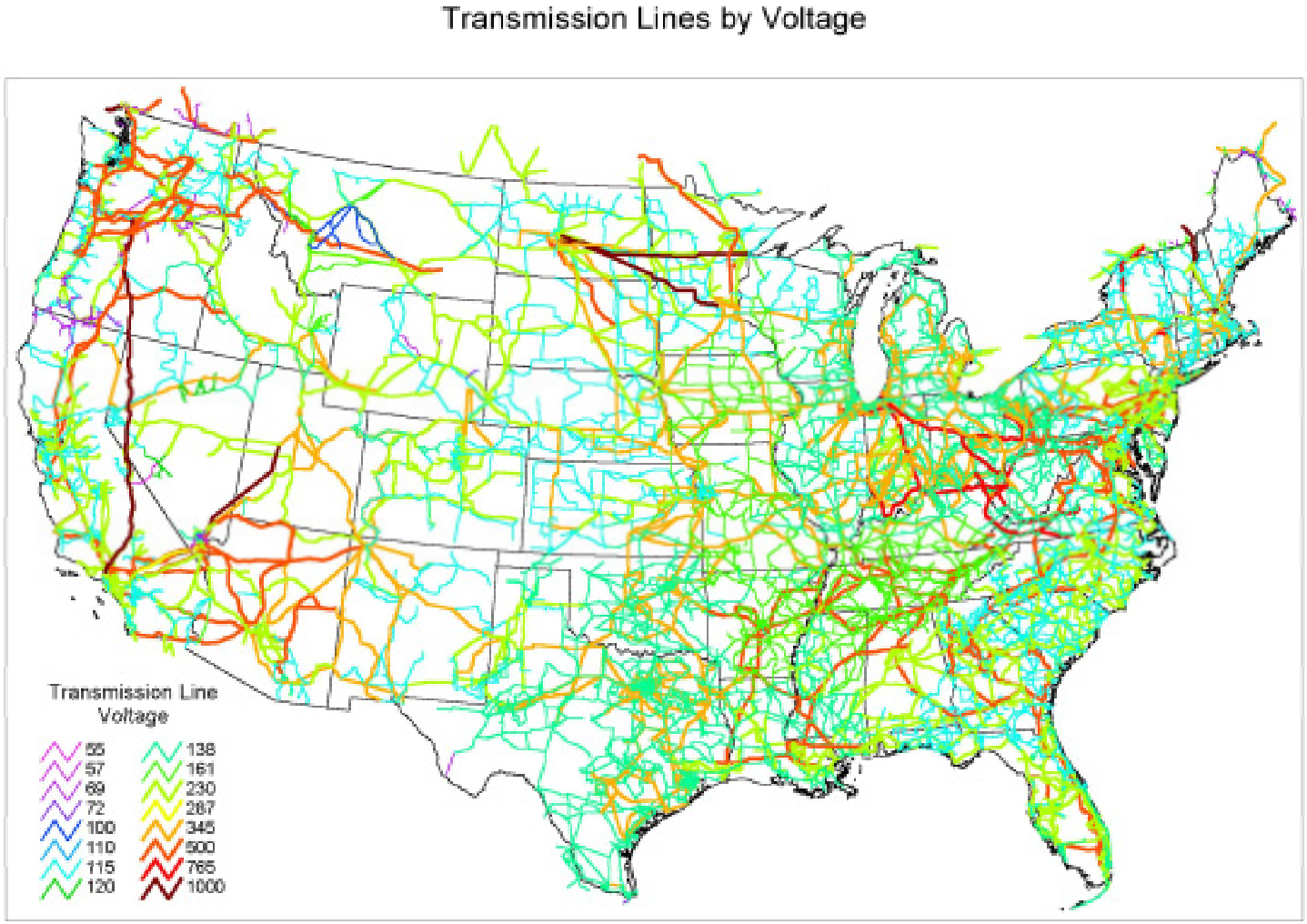
Latest NREL Wind Resource Data



Characteristics of Wind Resource Data

- Under development at NREL
- Both onshore and offshore with exclusions
- Offshore shallow and deep
- Classes 3 – 7
- Original data at the 200m and above level aggregated up to the WinDS regions

Transmission in WinDS

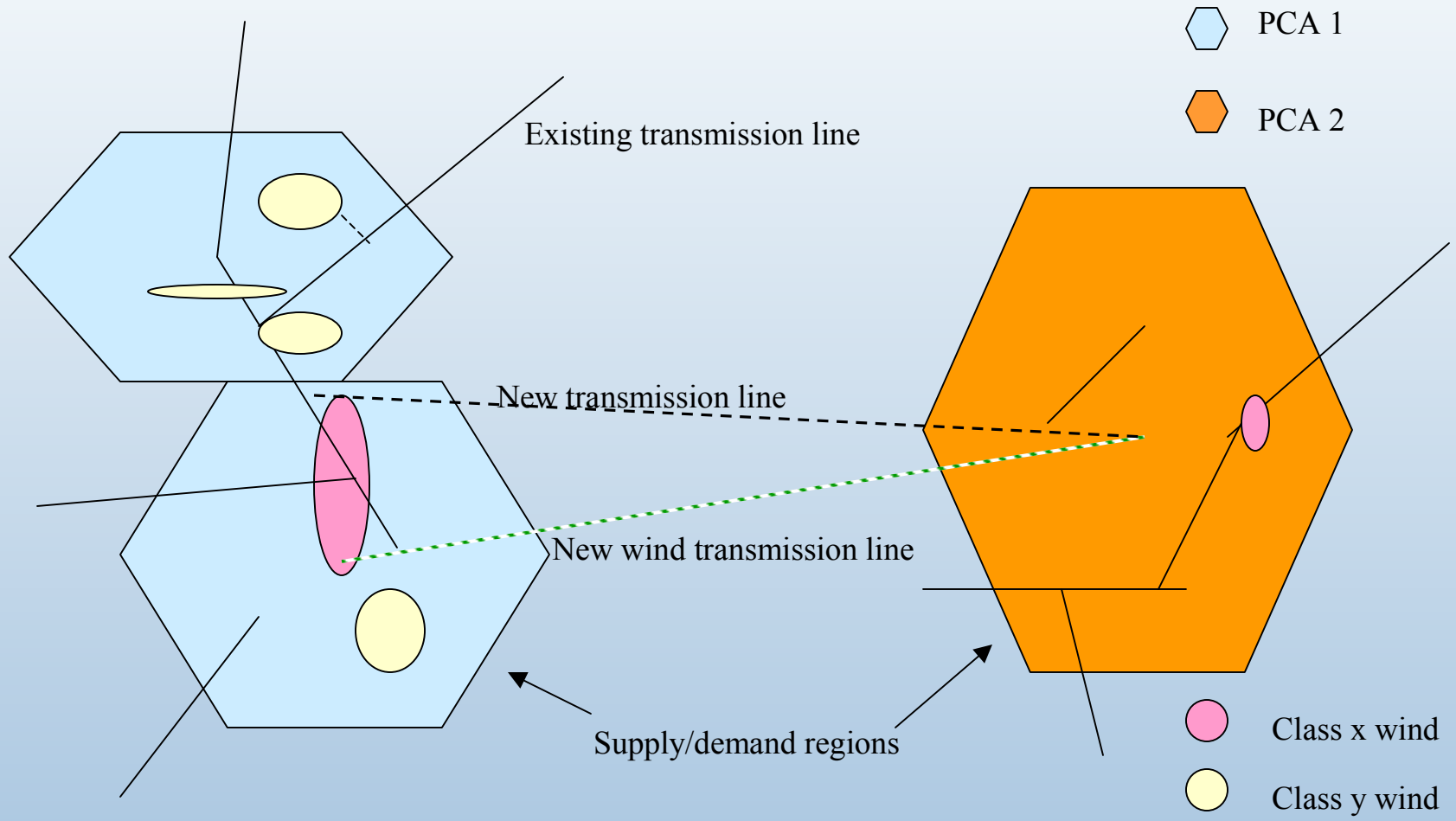


EAO Energy Analysis
Understanding Ener

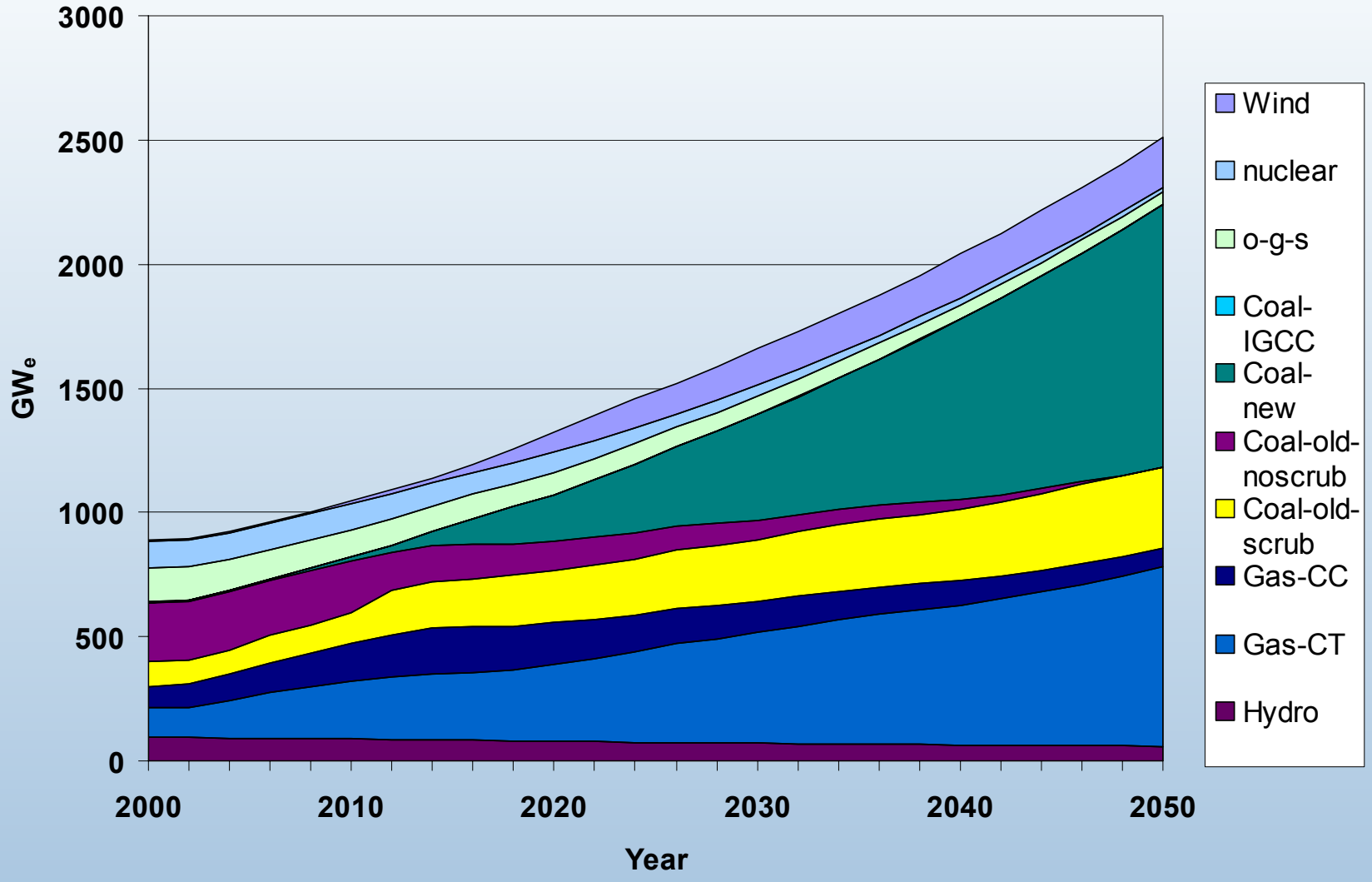
Characteristics of the WinDS Transmission Data

- Based on Platts/RDI PowerMap data base
- Includes all lines > 100 kV and some 69 kV lines
- MW capacity based on kV rating and length (distance between connections)
- Use GIS to identify and aggregate capacity crossing regional boundaries in the LP

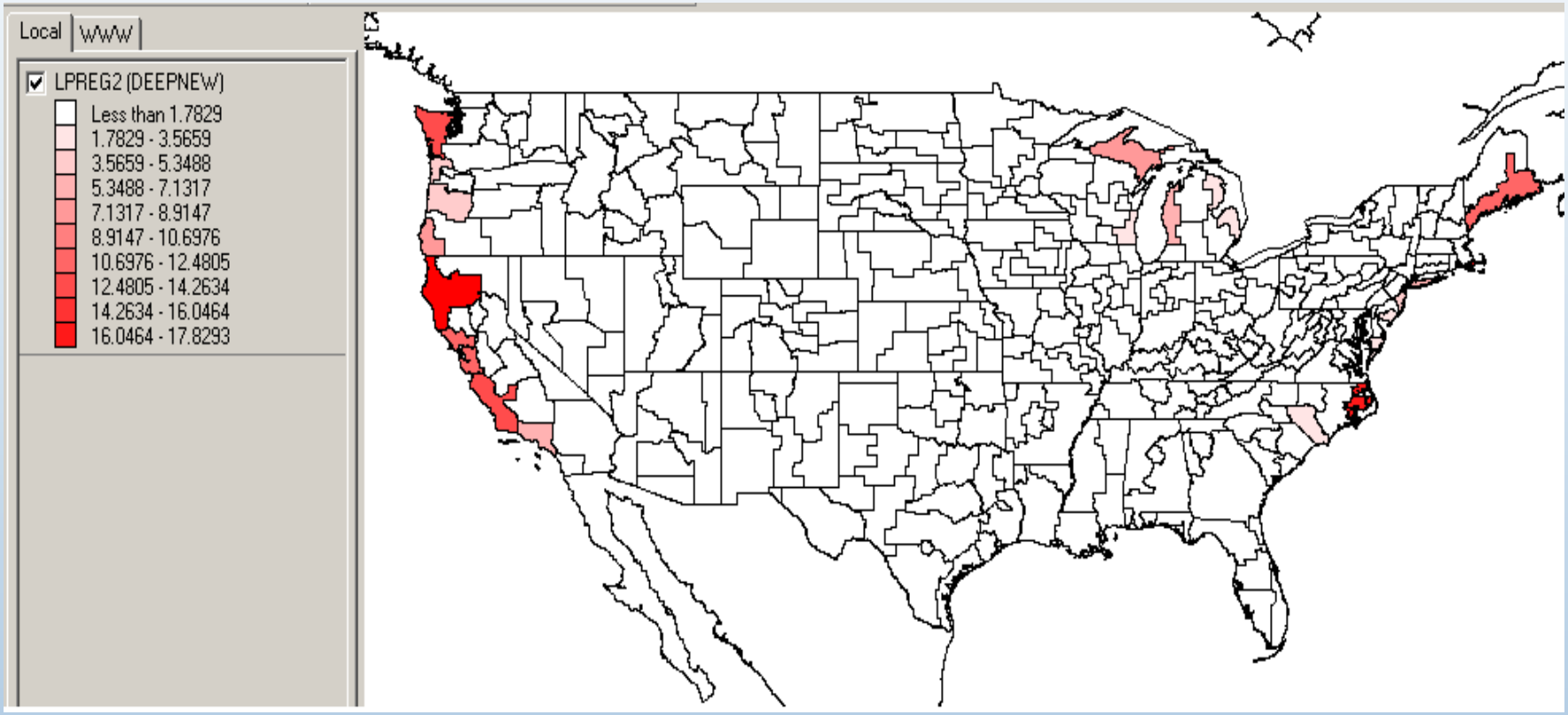
WinDS Constraints on Wind Transmission



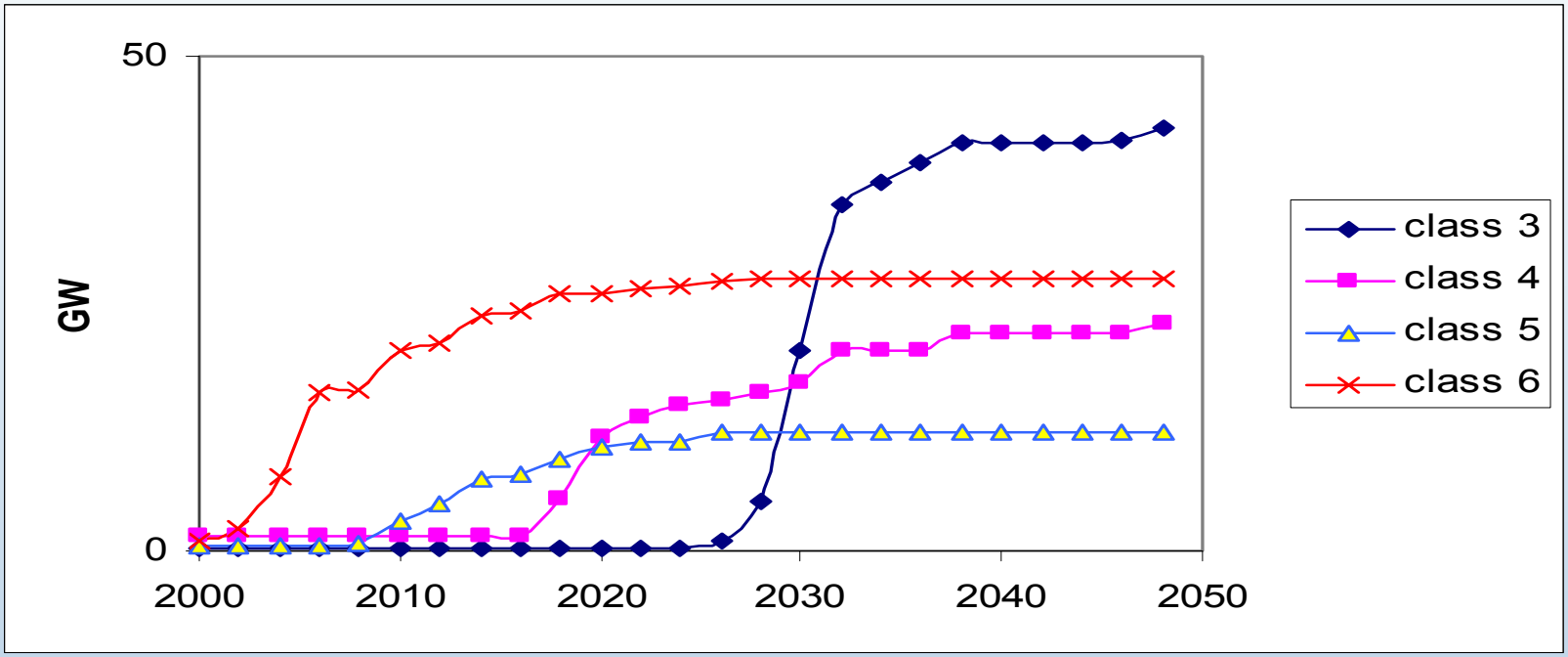
WinDS Results – Base Case



WinDS Offshore Installations in the Full R&D Case

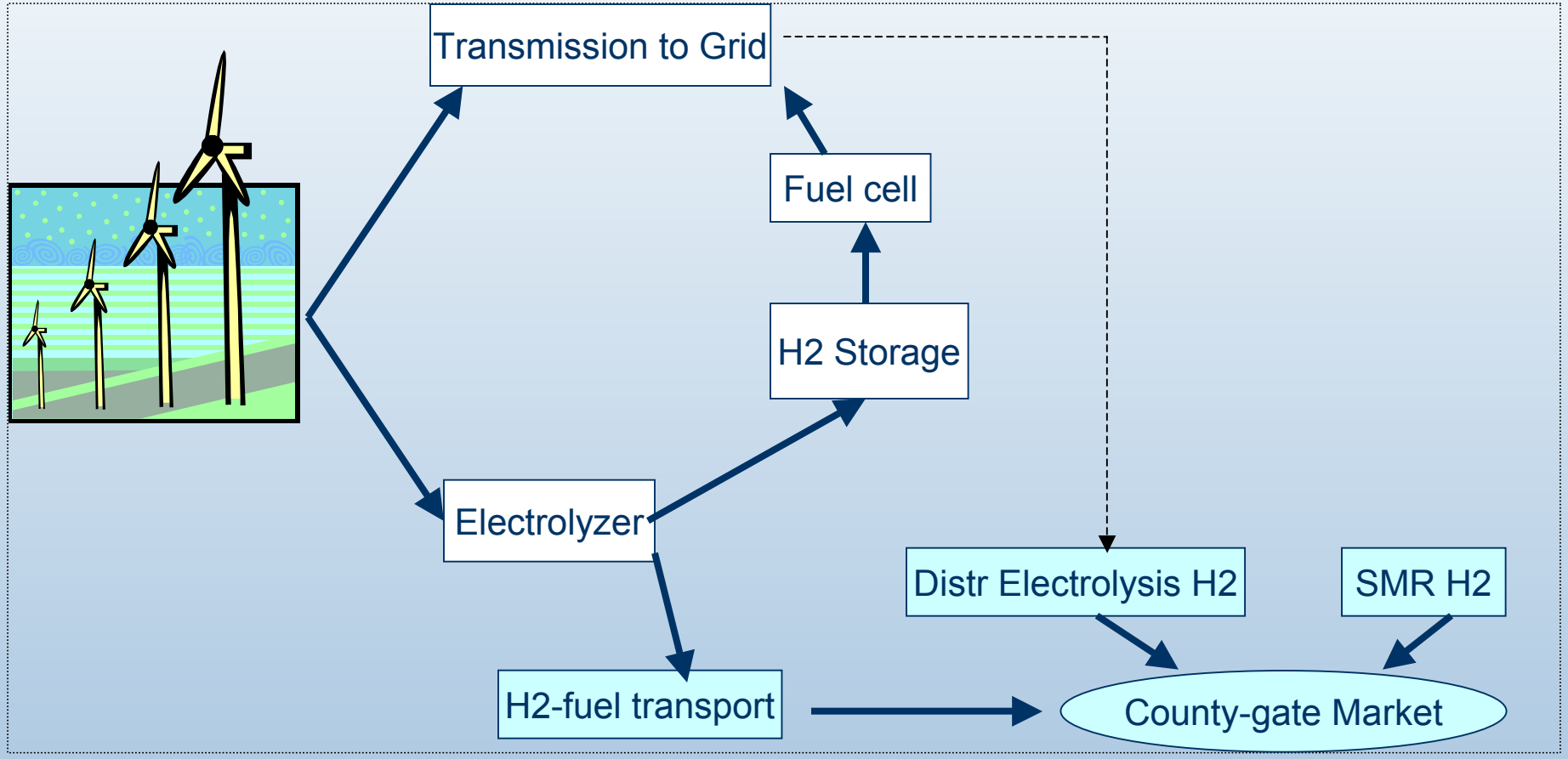


Benefits of WinDS Regional Disaggregation

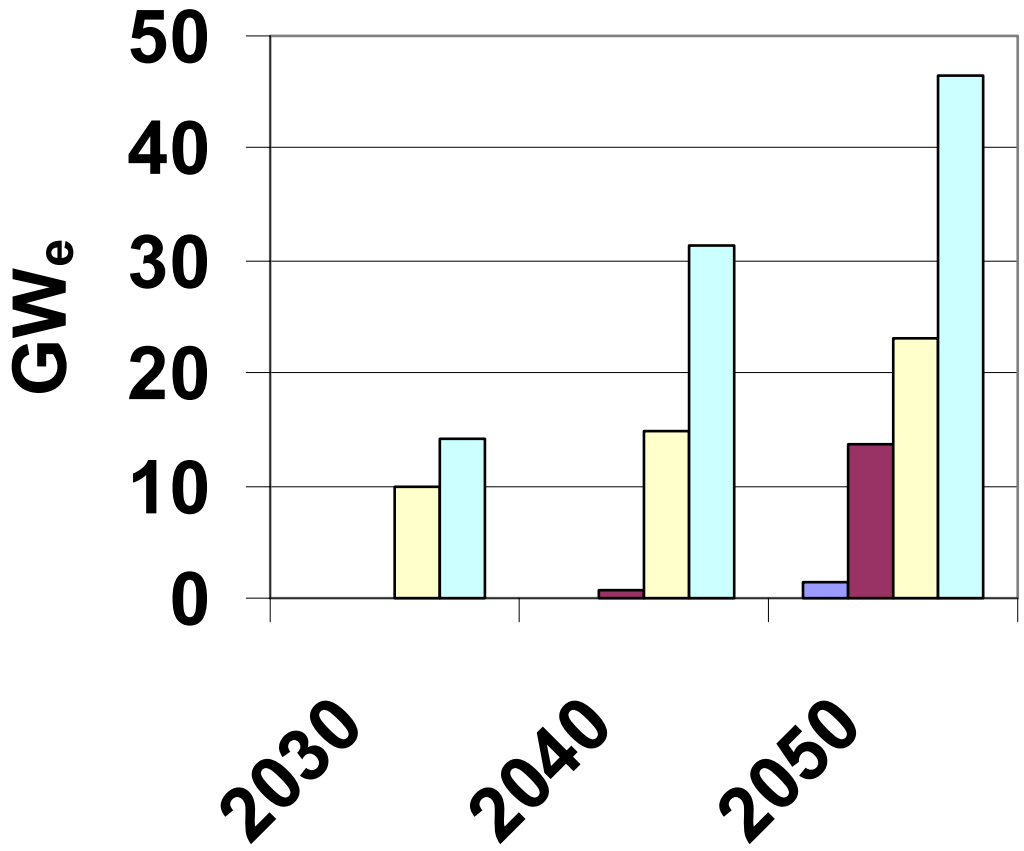


- Captures transmission distances and bottlenecks
- Captures wind dispersion effects
- Allows state policies to be represented
- Allows finer representation of conventional fuel price variations
- Allows utility concerns at the PCA level to be simulated

WinDS-H2


Transmission to Grid
Fuel cell
H2 Storage
Electrolyzer
Distr Electrolysis H2
SMR H2
H2-fuel transport
County-gate Market

WinDS-H2 Capacities
Base Case



- Fuel cells at wind farms
- Wind to electrolyzers at wind farms
- Add'l Wind direct to grid
- Distributed electrolyzers at load centers

GIS Inputs to the LP Portion of WinDS-H2

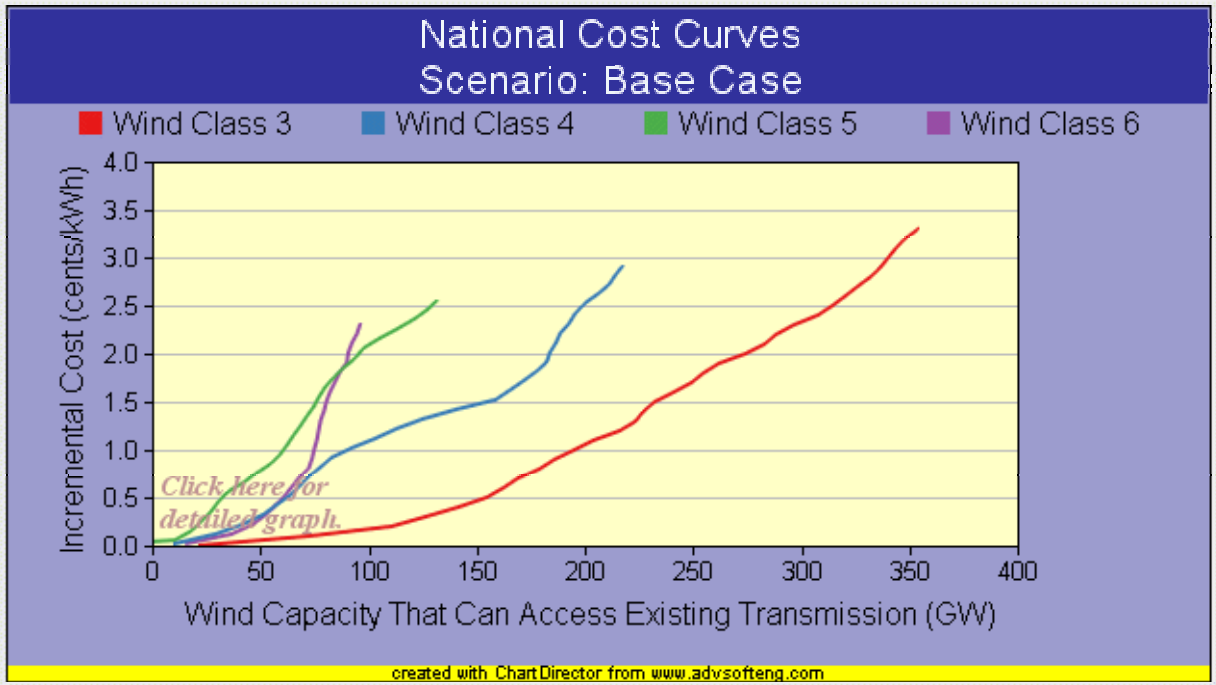
- Regional structure (subsets, center points)
- Electricity load and peak demand by PCA and wind region
- Existing conventional capacity by PCA
- Hydro energy by PCA
- Scheduled conventional capacity retirements by PCA
- Wind resources by class by wind region
- Existing wind capacity by wind region
- Wind-to-grid supply curve**
- In-region wind supply curve**
- Slope and population penalty data for wind
- Existing transmission capacity
  - Crossing borders of each wind region
  - From one PCA to a contiguous PCA
- Transportation fuel demand by wind region
- H2 inregion supply curves**
- Natural gas pipeline access by wind region/county

** Optimization within GIS

GIS-derived Supply Curves

- Two types
  - Cost to access grid
    - Assignment of wind resources to grid
    - GIS-based optimization
  - In-region supply
    - Two types
      - New intra-region transmission lines from wind to load
      - H2 pipelines from wind to load
    - GIS-based optimization

Input Costs to Build Transmission to Grid



Wind Power Class	Incremental Cost (cents/kWh)	Capacity (GW)	Cummulative Capacity (GW)
3	0.0¢	21.1	21.1
3	0.1¢	51.0	72.1
3	0.2¢	38.1	110.2
3	0.3¢	15.8	126.1
3	0.4¢	15.1	141.2
3	0.5¢	13.1	154.3
3	0.6¢	7.8	162.1
3	0.7¢	6.7	168.7

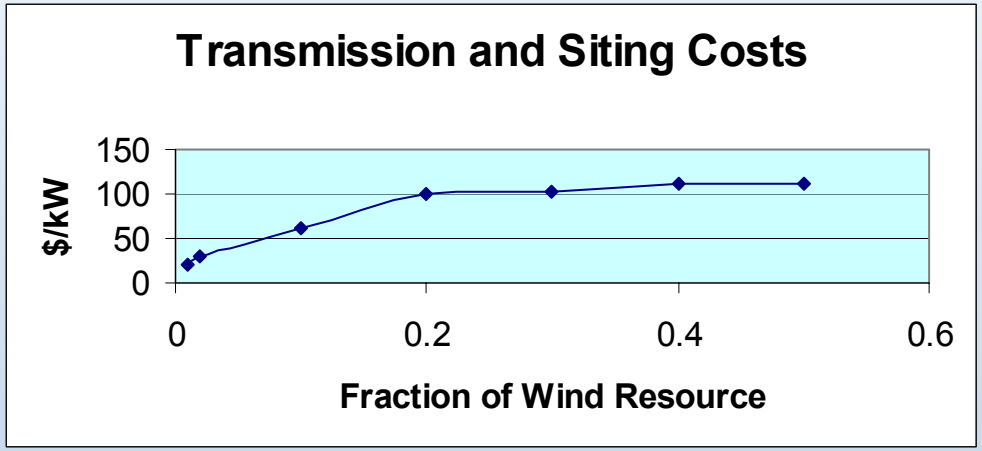
EAO Energy Analysis Office
Understanding Energy Issues

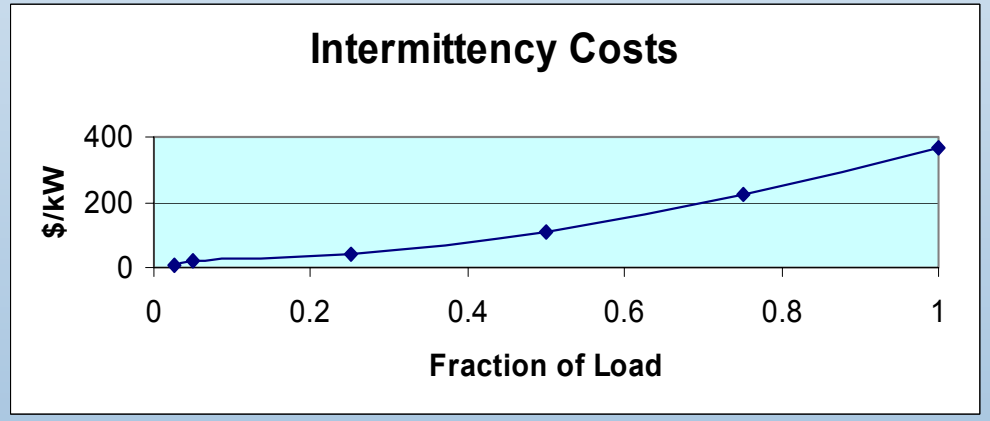
Laboratory

Reduced Form Supply Curves
Under Development

- Based on results from WinDS
- National and NERC region level
- Present total extra-generational costs as a function of wind penetration
  - Run a base case
  - Run again forcing the same level of wind but with all wind transmission costs set to zero.
    - Delta in objective function value divided by new wind capacity is the transmission cost adder per MW of wind
  - Run again forcing the same level of wind as base case, but with no intermittency degradation.
    - Delta in objective function value divided by new wind capacity is the intermittency cost adder per MW of wind

Hypothetical Wind Non-Generation Cost Supply Curve





- Transmission and siting costs
  - Build cost to reach grid or load center
  - Build cost to circumvent bottlenecks
  - Cost to use existing grid
- Costs of intermittency
  - Backup capacity
  - Operating reserves
  - Surplus wind

Regional/GIS Lessons Learned

- Regionalization: Beneficial, but there are limits
  - Data and computer requirements
  - Results evaluation
- Data not always available or may require further disaggregation:
  - e.g., gasoline consumption below the state level
- Some data available at such a fine level of detail that it has to be aggregated back up to use in other models:
  - e.g., wind resource data at 200m
- GIS can be used to do some optimization work, but it usually requires case-specific coding:
  - e.g., the supply curves for WinDS
- Lack of complete integration with the market model leads to some inaccuracies:
  - e.g., the wind-to-grid supply curve must assume a technology year for wind costs
- The large amount of GIS data required is bound to produce some oversights:
  - e.g., the exclusion data in the wind resource data for WinDS
- Difficult to modify the regional structure